COMPARISON OF VENEER PREPARATION DESIGN AND FRACTURE STRENGTH:
A THESIS

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Thesis submitted to the Faculty of the
AEGD 2 Year Graduate Program, United States Army, Fort Bragg, NC and
Uniformed Services University of the Health Sciences
In partial fulfillment of the requirements for the degree of
Masters in Oral Biology, 2017

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1.0 PROTOCOL TITLE: COMPARISON OF VENEER PREPARATION DESIGN AND FRACTURE STRENGTH RESISTANCE: A STUDY

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3.2 Does the research involve obtaining information about living individuals? 32 CFR 219.102(f)

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☒ No. **Activity is Research Not Involving Human Subjects** and therefore does not require IRB approval. *This is the box that you will most likely check.*

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☒ No. **Activity is Research Not Involving Human Subjects** and therefore does not require IRB approval. *This would be information that is available in the public domain.*

IRBNet Number:
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4.0 EXPECTED COMPLETION DATE FOR STUDY (INCLUDING DATA ANALYSIS): DEC 2016

5.0 SUMMARY:

Porcelain veneer restorations are a popular choice to restore worn, discolored and damaged dentition. The most attractive part of the restoration is the minimal preparation design which conserves tooth structure. Multiple designs over the years have been advocated by various practitioners. However, there is minimal consensus on a superior design. We will compare the fracture strength resistance of two extremely popular and current minimal preparation designs and thus determine which has the advantage in overall lifespan of a veneer restoration: the Butt Joint Preparation and Prepless Veneer designs.

5.1 DATA COLLECTION METHODOLOGY AND STATE THE STUDY HYPOTHESIS OR RESEARCH QUESTION:

A comparision between total fracture strength of Ceramic Veneers placed on two different preparation designs will be performed to determine which preparation design possesses the superior fracture strength resistance: the Butt-Joint preparation or the Prepless Veneer design.

5.2 DESCRIBE THE TYPE OF DATA OR SPECIMENS TO BE STUDIED:

Ivorine teeth manufactured by Columbia Dentiform simulating Maxillary Right Central Incisors will be used (Columbia Dentoform number x) . The specimens will be cut in two different design types: the Butt Joint preparation and the prepless veneer preparation type and will then be sent back to Columbia Dentiform to be duplicated. Twenty- five specimens per preparation design will be used for a total of 50 specimens. Ceramic veneers will be fabricated for each individual specimen using the CAD/CAM machine and cemented using Nexus dual cure resin cement. Additionally, 10 specimens will be used initially to calibrate the Instron unit device (model Apex T5000; Satec Systems Inc., Grove City, PA) prior to initiation of data collection.

5.3 NUMBER OF PARTICIPANTS:

Fifty total ivorine tooth samples will be tested and data will be collected from the test population.

5.4 DESCRIBE ANY CODING OF DATA OR SPECIMENS, INCLUDING INFORMATION ON WHO HOLDS THE KEY TO THE CODE:

none

5.5 MILITARY RELEVANCE:

Determination of the fracture strength resistance between the two most employed designs can help to determine which design can potentially last longer. This data can help to standardize a preparation principle advocated by DENCOM.

5.6 MEDICAL APPLICATION:

In addition to the information in section 5.5, the additional benefit of the study will also test specifically whether or not a minimal level of enamel reduction is *absolutely* necessary to achieve the desired fracture strength resistance, and still deliver the desired aesthetics of the final prosthesis.

6.0 PUBLICATION REQUIRMENTS: Proper WAMC publication clearance is required prior to all presentations, abstracts, and publications. The following require WAMC approval: reports involving WAMC subjects and/or patients, reports that cite WAMC in the title or byline, reports of WAMC approved clinical investigation or research, reports of research performed at WAMC, and reports of research conducted by WAMC assigned personnel.

The investigators will obtain proper OTSG publication clearance prior to all presentations, abstracts, and publications that involve traumatic brain injury, post-traumatic stress, poly-pharmacy, pain, or suicide.

The investigators must provide to the Department of Clinical Investigation a listing of presentations, abstracts, and publications arising from the study.

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7.0 SIGNATURES: Signatures are not required for Associate Investigators and Collaborators.

I verify that the contents of this proposal are accurate and that I have read and agree to comply with the statements above which outline my responsibilities as a Principal Investigator.

Principal Investigator Signature
Name and Date: STEVEN K. MAREK 11 FEB 2016

6.1 OTHER SIGNATURES FOR APPROVAL:

I concur with the submission of this proposal to the Department of Clinical Investigation for review and approval.

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Name and Date: Manuel Peláez LTC, DC 11FEB16

Department Chief Signature
Name and Date: Stacy L. Larsen LTC, DC 11 Feb 16

Regulatory Affairs Review

Name and Date

Scientific Review

Lisa A Franklin 12 Feb 2016

Name and Date

THESIS APPROVAL FORM

Submitted by Steven K. Mark in partial fulfillment of the requirements for the degree of Master of Science in Oral Biology.
Accepted on behalf of the Faculty of the Graduate School by the thesis committee:

Date	Manuel Pelaez, DMD Research Mentor
Date	Jason Bullock, DMD AEGD Assistant Director
Date	Stacy Larsen, DDS AEGD Program Director

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Philip Briales, Columbia Dentoform
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COL Stacy Larsen
LTC Young S. Kang
LTC Manuel Pelaez
MAJ Jason Bullock

Their participation, guidance and support contributed to the creation of this thesis.

DEDICATION

To my father, David Nuen Yuk Mark, MD
For his steadfast support in all adversity

For my mother, Oi Wah Chiu (Eva) Mark
For her love, kindness and strength

In Honor of my grandmother, Shui Ying Lam
For her temperance and generosity

Nothing is possible without their love and support.

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MAJ DC

17 APR 2017

ABSTRACT

COMPARISON OF VENEER PREPARATION DESIGN AND FRACTURE STRENGTH:
A THESIS

Steven K. Mark, DMD MAJ DC

Thesis directed by: LTC Manuel Pelaez, LTC Young S. Kang

Background: Aesthetic dentistry has been advocated by dentists since the early twentieth century, its limitations solely based upon the materials and methods to securely retain porcelain restorations to tooth structure. With the advent of a safe and predictable method to directly bond ceramic materials to enamel tooth structure, a number of methodologies have been advocated that preserve and maintain maximum tooth structure while achieving both the desired aesthetic results and longevity of the restorations. The purpose of this study is to compare the fracture strengths of two most popular and oft-promoted preparation designs and determine which is the superior product.

Methods: A total of fifty samples were fabricated from ivorine teeth replicating tooth number 8 (maxillary right central incisor) divided into two groups: twenty-five samples based upon the Butt-Joint veneer preparation and twenty-five samples based on the Prepless veneer design. A Sirona CAD/CAM system was employed to scan and mill lithium disilicate eMax veneer restorations for the ivorine teeth. The restorations were

subsequently cemented with resin cement onto each ivorine tooth and then placed at 135 degrees into a brass jig to simulate normal position. Each sample was placed on an Instron device and then loaded at 0.5mm/min until failure occurred. An ANOVA analysis was then utilized to review the data.

Results: The mean load at break (N) for the Prepless Peneer group was 344.47 (SD = 4.18), mean for Butt-Joint preparation M = 603.46, (SD = 189.67). Mean modulus (MPa) of the Prepless veneer group (M = 74.69, SD = 7.70) was greater than the mean of the Butt-Joint preparation samples (M = 44.45, SD = 15.52). Significant differences were found between the preparations for both extension at maximum load [$F(1, 48) = 4.49$, $p = 0.04$, $\eta_p^2 = 0.09$] and extension at break [$F(1, 48) = 4.47$, $p = 0.04$, $\eta_p^2 = 0.09$]. The mean extension at maximum load for the prepless veneer group was 0.79mm (SD = 2.18) and 2.41mm (SD = 3.13) for Butt-Joint preparation. The mean extension at break for the prepless veneer group was 0.80mm (SD = 2.18) and 2.41mm (SD = 3.13) for Butt-Joint preparation. No difference was found between the groups with respect to maximum load, $p = 0.69$.

Conclusions: The Butt-Joint veneer design can withstand a greater load at failure and tolerate a greater extension at load than the Prepless veneer design. The Maximum Load at break (Fracture Strength) tolerated by both designs is very similar. The Butt-Joint design displays favorability towards (in order of frequency) static fractures, cohesive fractures and adhesive fractures. The Prepless veneer design displayed a tendency towards more cohesive failures versus static failures. Fabrication of the Butt-Joint veneer restoration was facilitated by definitive margins whereas the Prepless design was an arbitrary design with margins defined by the author and not any preparation.

Aesthetically, the Butt Joint designs were more pleasing with minimal issues with cleansability, positive seating of the restoration. The author concludes the Butt-joint veneer design is the superior preparation design for aesthetic cases.

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INTRODUCTION

STATEMENT OF THE PROBLEM

The concept of Aesthetic Dentistry is not a new topic of discussion. Indeed it was Dr. Charles Pincus in 1938 who is credited with the first mention of veneering Hollywood actors' teeth with denture bonding adhesive to create radical smile makeovers for close-up scenes during movie production[1]. Over many subsequent decades, both companies and dentists alike have employed the use of various types of materials and methods for the purpose of creating an aesthetically pleasing dentition desired by their patients. Previously, such restorations were either temporary in nature or required full coverage prostheses for long lasting effects. Many were neither conservative nor aesthetically correct. Not until 1955 did Buonocore[2] describe the process in which acid etching could increase the total surface area of the tooth and enhance direct bonding without sacrificing tooth structure. Calamia[3] and Horn[4] took this concept further and advocated a process in which porcelain laminate restorations could be directly bonded to tooth structure with resin-based cement systems via acid etching. This innovative process resultantly created a wealth of possibilities for both patients desiring change and dentists eager to explore new methodologies and materials. Porcelain Veneers can be employed for a variety of physiologic issues[5] that patients have, including: diastema

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[1]Dumfahrt H. Porcelain laminate veneers. A retrospective evaluation after 1 to 10 years of service: Part I--Clinical procedure. Int J Prosthodont. 1999 Nov-Dec;12(6):505-13.
[2] Buonocore, MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res. 1955 Dec;34(6):849-53.
[3] Calamia JR. Etched porcelain facial veneers: a new treatment modality based on scientific and clinical evidence. N Y J Dent. 1983 Sep-Oct;53(6):255-9.
[4] Horn HR. A new lamination: porcelain bonded to enamel. N Y State Dent J. 1983 Jun-Jul;49(6):401-3.
[5] Calamia JR, Calamia CS. Porcelain laminate veneers: reasons for 25 years of success. Dent Clin North Am. 2007 Apr;51(2):399-417, ix.

closure; restoration of lost / fractured tooth structure; tooth discolorations, such as hypocalcifications, fluorosis and tetracycline staining; correction of defects resulting from diseases such as Amelogenesis Imperfecta and Fluorosis; and the correction of malformed teeth (e.g. peg lateral incisors).

Modern cement systems employ a dual-cure resin based option to facilitate the delivery process for the patient based upon this level of research. However, it can be the most critical aspect of the treatment: it is often cited as the primary reason restorations fail within the first 24-48 hours of delivery due to moisture contamination, voids at the margins, insufficient bond material, and the like[6]. Numerous ceramic materials are available today, each offering advantages to a given situation depending on the amount of tooth structure remaining after preparation and the materials' inherent mechanical properties to withstand occlusal forces.

SIGNIFICANCE

We can appreciate the fact that today we have very capable cement systems and materials to fabricate veneers. One essential question persists, however. That there is not a true consensus as to the type of porcelain veneer preparation that would enable the long-term strength and survivability of the restoration is troubling. To date, various

[6] Sheets CG, Taniguchi T. Advantages and limitations in the use of porcelain veneer restorations. J Prosthet Dent. 1990 Oct;64(4):406-11.

practitioners have advocated no less than four preparation designs[7] over twenty-five years of continuous study:

1. *Facial Window* preparations that preserves the Incisal edges of the underlying dentition
2. *Butt-Joint* preparations which overlap the Incisal edge of the tooth structure
3. *Palatal Chamfer* preparations that include a 2mm chamfered edge on the palatal or lingual aspect of the tooth structure
4. *Feather-edged* preparations that create an incisal edge both in porcelain and enamel.

(a) (b) (c)

Figure 1: Schematic illustration of Incisal preparation designs for Porcelain laminate veneers:
a. Feathered Incisal edge; b) Butt joint; c) Palatal chamfer[8]

[7] Shetty A, Kaiwar A, Shubhashini N, Ashwini P, Naveen D, Adarsha M, Shetty M, Meena N. Survival rates of porcelain laminate restoration based on different incisal preparation designs: An analysis. J Conserv Dent. 2011 Jan;14(1):10-5. doi: 10.4103/0972-0707.80723.

[8] da Costa DC, Coutinho M, de Sousa AS, Ennes JP. A meta-analysis of the most indicated preparation design for porcelain laminate veneers. J Adhes Dent. 2013 Jun;15(3):215-20. doi: 10.3290/j.jad.a29587.

Multiple options exist to restore veneers with different *materials*, including *Fired Feldspathic Porcelains* and *Pressed Feldspathic Porcelains. Fired Feldspathic Porcelains* can be fabricated as thinly as 0.3mm in thickness, and currently available products include: IPS design (Ivoclar), HeraCeram (Heraeus Kulzer), Creation (Jensen), Lumineers by Cerinate (DenMat)*, and Omega 900 (Vita Zahnfabrik). *Pressed Feldspathic Porcelains* can have a thickness as low as 0.5-0.7mm and available products include: IPS Empress (Ivoclar), Authentic (Microstar) and OPC (Jeneric Pentron)[1], some of which require no preparation as described by their respective manufacturers. Current materials and technology has ventured into CAD/CAM (computer assisted design / computer assisted manufacturing) design and fabrication of single and multiple unit restorations. The milling chamber can utilize a number of different materials depending on the choice of the dentist, the dimensional parameters of the preparation and choice of restoring material. This includes Feldspathic porcelain, leucite reinforced silicates, lithium disilicates (including eMAX) and zircona-based restorative materials.

Prepless design systems gained some popularity when the products and methods were first advertised in the late 1990's by several companies. One company worth mentioning is DenMat (based in California), which fabricates the Lumineers prepless veneer system. The company advertises its proprietary prepless design, fabrication and delivery system as painless, requiring minimal to no anesthesia for the procedure and produces the same aesthetic results and strength as a conventional porcelain veneer preparation and placement[9].

[9] DenMat Holdings, LLC. DenMat's Cerinate One-Hour permanent veneers make porcelain smile makeovers affordable. Compend Contin Educ Dent. 2012 Jan;33(1):74-5.

Is there clearly an ideal choice available to the practitioner, one that can be employed in any situation that yields the greatest strength and aesthetic result required by patient and doctor alike? There is consensus that there are several preparation types which can be employed in any number of clinical situations, but which one enables the *superior* level of aesthetics, form, function, and longevity we require? We can, upon practical testing and interpretation of results, potentially advocate one ideal mode of therapy for patients who qualify and are willing to perform this treatment. This would enable our practitioners to utilize a standard method of treatment that is proven to be reliable and delivers the aesthetics desired by our patients.

REVIEW OF LITERATURE

It should be no surprise that there is a wealth of material available detailing the process of veneer preparation, and bonding, as well as longitudinal studies evaluating clinical preparation designs and their strengths and weaknesses. Considering Dr. Pincus' first mention, the process was not deemed practical until Dr. Buonocore first mentioned the concept of *acid etching*[10] and its ability to increase the chemical and mechanical bond strength to enamel surfaces. Buonocore decidedly felt that acid treatment of enamel could render such treated surfaces "more receptive to adhesion"[11] in a similar manner to metals:

"*The increased adhesion obtained… on treated enamel surfaces may be due to*

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[10] Buonocore mg. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J dent res. 1955 dec;34(6):849-53.
[11] ibid

several factors, such as: (a) a tremendous increase in surface area due to the acid etching action; (b) the exposing of the organic framework of enamel which serves as a network, in and about which the acrylic can adhere; (c) the formation of a new surface due to precipitation of new substance, for instance, calcium oxalate, organic tungstate complex, and so on, to which the acrylic might adhere; (d) the removal of old, fully reacted, and inert enamel surface, exposing a fresh, reactive surface more favorable for adhesion; and (e) the presence on the enamel surface of an adsorbed layer of highly polar phosphate groups, derived from the acid used. Regardless of the mechanisms involved, however, we do know that we can increase adhesion remarkably by acid treatments due to a great increase in surface area and that the effect may be purely a physical phenomenon, with other acids capable of producing the same result."[12]

Calamia's research with Simonsen in the early 1980's further improved upon Buonocore's observations. They tested comparative bond strengths of enamel prepared with acid etching and bonding of resin to porcelain restorations. Bowen performed a similar study in which silica could be used[13]. Strengths of 7.5MPa (or 1100 psi) were recorded and it was deemed more than sufficient to retain such restorations.[14] Combined with the concept that the porcelain used to restore the tooth should also be acid etched with *Hydrofluoric acid* and an additional subsequent coating of Silane as a coupling agent, the strength of the bond formed was increased exponentially[15].

[12] ibid
[13] Bowen, R. L. Development of LI silica-resin direct filling material. Report 6333. Washington: National Bureau of Standards, 1958.
[14] Calamia JR. Etched porcelain veneers: the current state of the art. Quintessence Int. 1985 Jan;16(1):5-12.
[15] Ibid

Composite to Porcelain Bond	
Lightly Sandblasted but Unetched Veneer	230 PSI
20 Minute Etched Veneer	1672 PSI
20 Minute Etched Veneer + Silane	2083 PSI
Lightly Sandblasted but Unetched Veneer + Silane	1200 PSI

Calamia & Simonsen
Reported IADR – Dallas 1984

Fig. 1 Average bond strengths reported using different attachment techniques.

(Figure 2: Calamia, 1985)

Calamia notably described the preparation design he believed is most beneficial to the success of the restoration in his initial studies. A minimal chamfer preparation in enamel, 0.5mm deep and 0.5 to 1mm incisal to the cervical line is placed, along with a mesiodistal extension 0.5 mm into enamel, terminating facially to the interproximal contact.[16] This preparation persists as one of the most widely accepted designs for veneer restorations twenty-five years later.

[16] Ibid

Fig. 2 Facial view of recommended preparation. Note: The preparation is usually restricted to enamel.

(Figure 3: Calamia, 1985)

It is of particular interest that Calamia placed special emphasis on the concept of *treatment planning*, which has a direct influence upon the level of success of any case that a dentist may select to analyze and pursue. Analysis of the patient's occlusion on mounted study casts on an appropriate articulator, diagnostic wax-ups to explore and propose treatment design, conservative preparations, proper selection of ceramics, the materials and method of cementation, sufficient polishing and finishing of the restorations, and proper planning for the continued maintenance of the restorations all build to success for the case[17].

As clinicians we are concerned not only with the feasibility of executing and delivering such cases, but also with the overall strength, longevity and potential sequelae

[17] Calamia JR, Calamia CS. Porcelain laminate veneers: reasons for 25 years of success. Dent Clin North Am. 2007 Apr;51(2):399-417, ix.

following restoration of the dentition.   Friedman is among many who have done so, and described his observations on a 15-year review of veneer restorations[18].

(Figure 4: Friedman, 1998)

Friedman appropriately questioned the *quantity* of tooth structure reduction necessary to restore with porcelain veneers. He described his observations during the 1980’s-1990’s time period where practitioners, in his opinion, sought to correct problems patients had with color, size and shape with aggressive preparation designs. Moreover, Friedman described options for treatment available to the patient that could achieve similar results *without any* tooth preparation, such as orthodontic therapy and bleaching.

Dumfahrt and his colleagues subsequently conducted numerous studies that revealed long-term success of veneer restorations.   His three-part longitudinal study evaluated the quality of 191 porcelain laminate veneers and explored the gingival response (margin index, papillary bleeding index, sulcus probing depth, and increase in

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[18] Friedman MJ. A 15-year review of porcelain veneer failure--a clinician's observations. Compend Contin Educ Dent. 1998 Jun;19(6):625-8, 630, 632.

gingival recession). The clinical examination was performed and the results were statistically evaluated, with a resulting failure rate of 4%[19]. Marginal integrity proved to be acceptable in 99% of the subjects tested and excellent in 63%. His conclusions were that porcelain laminate veneers offer a predictable and successful treatment modality that preserves a maximum of sound tooth structure[20] with increased risk of failure when veneers are partially bonded to dentinal surfaces. Furthermore, he estimated survival probability in a ten-year period at 91%[21].

Fig 4c Posttreatment facial view.

Fig 4d At 81 months after placement, the patient shows multiple cracks on both veneers, mainly at the gingival third. The cracks were probably caused by distortion of the teeth under pathologic occlusal load.

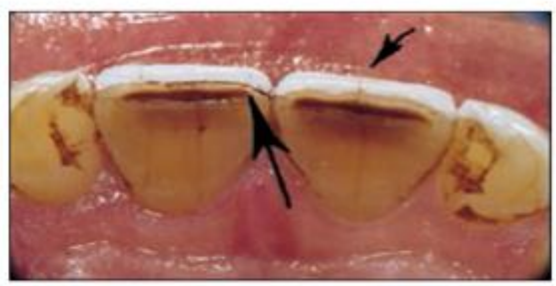

Fig 4e Superficial marginal discoloration is visible at the incisal margin *(large arrow)*. Some of the fracture reaches the incisal edge and seems to continue within the tooth structure *(small arrow)*. At this crack, color penetrates in a pulpal direction.

(Figure 5: Dumfahrt, 1999)

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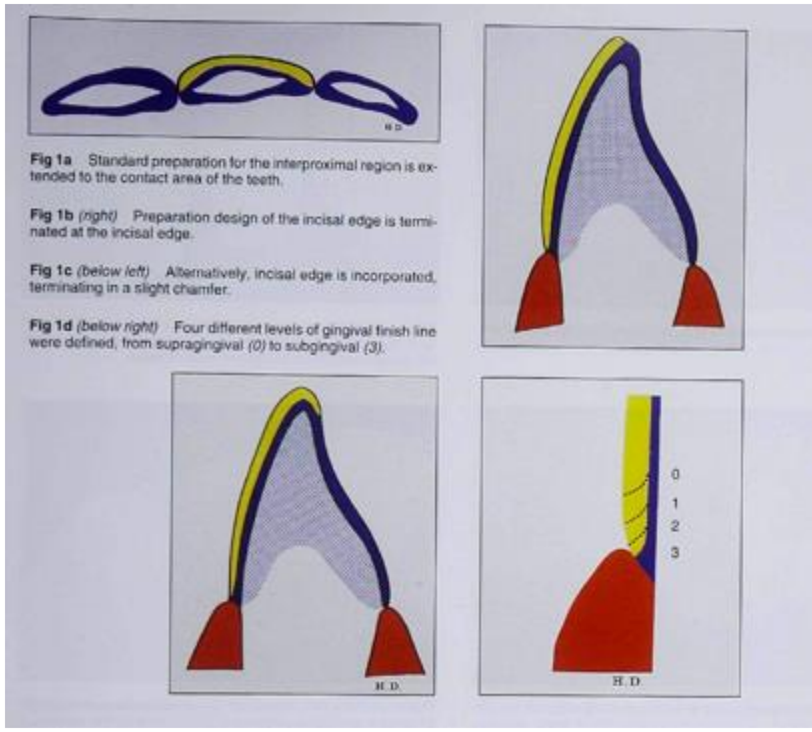
[19] Dumfahrt H. Porcelain laminate veneers. A retrospective evaluation after 1 to 10 years of service: Part I--Clinical procedure. Int J Prosthodont. 1999 Nov-Dec;12(6):505-13.
[20] Dumfahrt H, Schäffer H. Porcelain laminate veneers. A retrospective evaluation after 1 to 10 years of service: Part II--Clinical results. Int J Prosthodont. 2000 Jan-Feb;13(1):9-18.
[21] Dumfahrt H. Porcelain laminate veneers. A retrospective evaluation after 1 to 10 years of service: Part I--Clinical procedure. Int J Prosthodont. 1999 Nov-Dec;12(6):505-13.



(Figure 6: Dumfahrt, 1999)

(Figure 7: Beier, Dumfhart, 2012)

318 anterior porcelain veneer restorations were placed in eighty-four subjects (38 men, 46 women) between 1987 and 2009 at the Medical University of Innsbruck (Innsbruck, Austria) and subsequently followed in a subsequent clinical study performed by Dumfahrt and Beier. It evaluated the clinical quality, success rate, and estimated survival rate of anterior veneers made of silicate glass ceramic in a long-term analysis of twenty years[22]. The longitudinal study indicated that the lifespan of the veneers is variable after the fifteen to twenty-year mark. Patients with bruxism were also accounted for (50% of the population) and the total survival rates of the restorations were similar[23].

Layton's[24] study involved 304 feldspathic veneers placed on maxillary canines, incisors and premolars using a preparation design with chamfer margins, incisal reduction and palatal overlap bonded primarily to enamel with resin cement based systems. All veneers were maintained in-situ for a minimum of one to six years. 180 veneers remained for a period of five to eleven years, and sixty-one remained for ten to sixteen years. Failures observed by Layton occurred in fourteen patients with sixteen units total, but these failures occurred in the first to second years and the thirteenth to fourteenth years respectively. When the restorations are bonded to enamel, Layton summarized the survival rate at 96% $\pm$ 1% for a period of at least 6 years, and the cumulative survival rate was 73% $\pm$ 16% at the sixteen year mark[25]. Layton freely admitted that there were

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22 Beier US, Kapferer I, Burtscher D, Dumfahrt H. Clinical performance of porcelain laminate veneers for up to 20 years. Int J Prosthodont. 2012 Jan-Feb;25(1):79-85.
23 Ibid
24 Layton D, Walton T. An up to 16-year prospective study of 304 porcelain veneers. Int J Prosthodont. 2007 Jul-Aug;20(4):389-96.
25 Ibid

limitations to the study: the number of subjects were small, short follow-up times were common, and the failure criteria did not include aesthetic failures[26].

Given the right conditions and sound clinical skill, porcelain veneer restorations can therefore last a minimum of ten years. An excellent definition of veneers is given by Lacy. He described the preparation design for porcelain laminate veneers should simultaneously "allow an optimum *marginal adaptation* of the final restoration and reflect an utmost respect for the hard tissue morphology. In the cervical and proximal areas, the creation of a light chamfer without internal line angles is universally accepted. Such a finish line will allow maximum preservation of enamel and will therefore also prevent marginal microleakage"[27].

Pascal Magne's research on design optimization for bonded ceramic veneers clearly demonstrates that, with regards to preparation design, the palatal extension should not reach beyond the palatal concavity[28]. Intact and fractured incisors were investigated using eight porcelain veneer designs with Chamfer and Butt-Joint finish lines. A 50-Newton horizontal force was applied to the incisal edge from a palatal direction to simulate functional load and stress distributions. Margins of restorations with limited incisal overlap showed *low* tensile and compressive stresses, contrasting those that

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26 Ibid

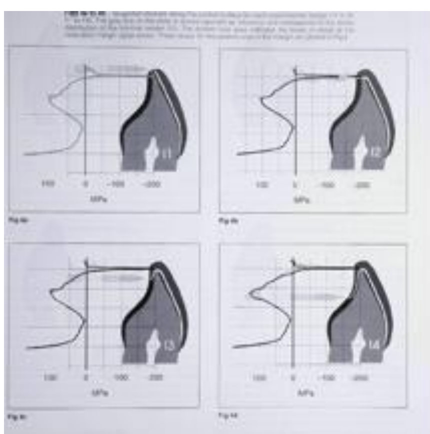
27 Lacy AM, Wada C, Du W, Wataiiabt L In vitro microleakage at the gingival margin of porcelain and resin veneers, J Prosthet Dent 1992;67:7-10.

28 Magne P, Douglas WH. Design optimization and evolution of bonded ceramics for the anterior dentition: a finite-element analysis. Quintessence Int. 1999 Oct;30(10):661-72.

extended into the palatal concavity were subjected to the *highest* tensile stresses[29]. Preparation designs incorporating long chamfers into the palatal concavity are thus unfavorable due to ceramic extensions in tooth areas where tensile stresses are maximally concentrated. Magne thus recommended mini-chamfers or incisal Butt-Joint margins, especially in the presence of moderate crown fractures or severe wear.

TABLE 1 Test conditions

Initial clinical situation	Code	Type of palatal finish line
No fracture	I1	No incisal overlap
No fracture	I2	Butt margin
No fracture	I3	Chamfer
No fracture	I4	Long chamfer in the palatal cavity
Moderate crown fracture	F1	Butt margin
Moderate crown fracture	F2	Chamfer
Severe crown fracture	F3	Butt margin
Severe crown fracture	F4	Chamfer



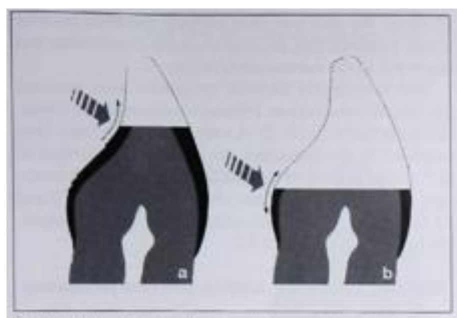


Fig 2 Moderate (a) and severe (b) coronal fracture. *(arrows)* Possible locations of the palatal fracture line: in the area of the palatal concavity for the moderate fracture (a) and in the area of the tubercule convexity for the severe fracture (b). The 2 areas suggest that the potential behavior regarding stress distribution in the area of the future restoration margin may differ.

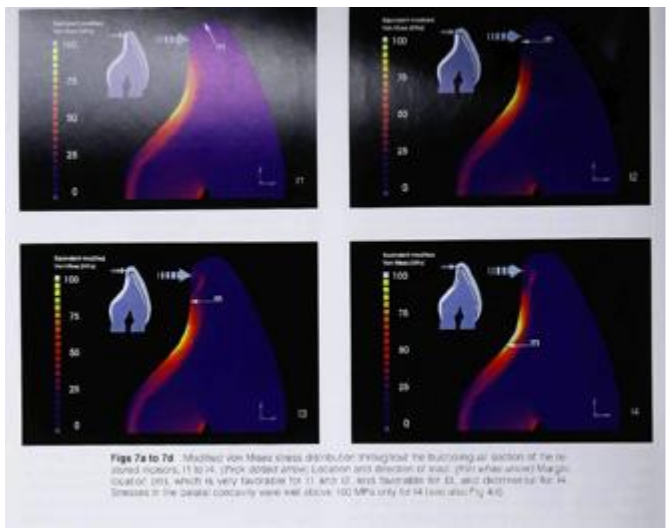
(Figure 8: Magne, 1999)

29 Ibid

TABLE 2 Material properties		
Material	Elastic modulus (GPa)	Poisson's ratio
Composite	20	0.24[†]
Ceramic	78[*]	0.28[‡]
Enamel	50	0.30[†]
Dentin	12	0.23[§]

[*] Data from the manufacturer of Creation Dental Porcelain (Klema).
[†] Craig.[15]
[‡] Anusavice and Hojjatie.[16]
[§] Watts et al.[17]

(Figure 9: Magne, 1999)



(Figure 10: Magne, 1999)

Similarly, Hahn and Gustav[30] confirmed that lingual chamfer preparation designs have the *lowest* fracture strength as compared to facial reduction or no reduction. Stappert also concluded that fractures in veneer restorations with palatal chamfers were significantly higher[31]. Schmidt's results also were the same[32].

30 Hahn P, Gustav M, Hellwig E. An in vitro assessment of the strength of porcelain veneers dependent on tooth preparation. J Oral Rehabil. 2000 Dec;27(12):1024-9.

31 Stappert CF, Ozden U, Gerds T, Strub JR. Longevity and failure load of ceramic veneers with different preparation designs after exposure to masticatory simulation. J Prosthet Dent. 2005 Aug;94(2):132-9.

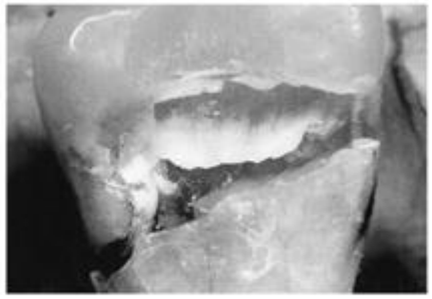


Fig. 4. Representative longitudinal fracture (Group IOP) observed after masticatory simulation and load-to-fracture testing.

(Figure 11: Stappert, 2005)

A meta-analysis of the existing literature on preparation design and fracture strength was conducted by DaCosta *et al*.[33] The authors stated that more long-term in vivo longitudinal studies are absolutely necessary to draw further conclusions as to the exact stability of the aforementioned preparation designs:

> *"The best manner of evaluating the performance of a procedure is by means of clinical studies. To date, however, the number of such longitudinal studies that have clinically assessed the different types of preparations for veneers is insufficient to enable a meta-analysis to be performed."*[34]

Da Costa concurred with Magne[35], who stated that the preparations should *not* terminate in the palatal concavity of the tooth structure, where occlusal stress forces concentrate the most and result in significant failure. Da Costa further stated that with the number of the studies that are available, the relative low numbers of appropriate test subjects (with specific restoration and preparation design) keeps the *statistical power* of

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32 Schmidt KK, Chiayabutr Y, Phillips KM, Kois JC. Influence of preparation design and existing condition of tooth structure on load to failure of ceramic laminate veneers. J Prosthet Dent. 2011 Jun;105(6):374-82.

33 da Costa DC, Coutinho M, de Sousa AS, Ennes JP. A meta-analysis of the most indicated preparation design for porcelain laminate veneers. J Adhes Dent. 2013 Jun;15(3):215-20. doi: 10.3290/j.jad.a29587.

34 Ibid

35 Magne P, Douglas WH. Design optimization and evolution of bonded ceramics for the anterior dentition: a finite-element analysis. Quintessence Int. 1999 Oct;30(10):661-72.

the literature resultantly low[36]. Nevertheless, Da Costa summarized his findings as the following:

a. Preparations of the *Feathered Incisal Edge* and *Palatal Chamfer Type* showed a reduction in the strength of the whole tooth
b. Fracture strengths of teeth prepared with *Butt-Joint* design showed *no reduction* in strength as compared with normal teeth
c. Fracture strengths of all preparation types were similar to one another
d. *Frequency of fractures in ceramic is greater in Palatal Chamfer design* than with *Feathered Edge*. Between the *Chamfer* and *Butt-Joint* designs, no statistical difference in fractures was observed.

Shetty[37]conducted a meta analysis akin to Da Costa, researching the four main preparation designs: window preparations with intact incisal edges; Butt-Joint preparations with 2mm incisal reduction; 2mm palatal Chamfer extensions; Feather-edge designs with incisal edges in enamel and porcelain. His conclusions were the Butt-Joint Preparation design possessed a 93% high survival rate due to its superior stress distribution, better aesthetics, positive seating and fracture resistance. Shetty also determined the following: the Window preparation is most conservative, Incisal coverage is better than none at all, Butt-Joint and overlap are the best overall designs, there was a need for more longitudinal studies in vivo, the Incisal Butt-Joint design is preferred for worn and fractured teeth, and the Incisal overlap preferred for healthy normal teeth with sufficient thickness.[38]

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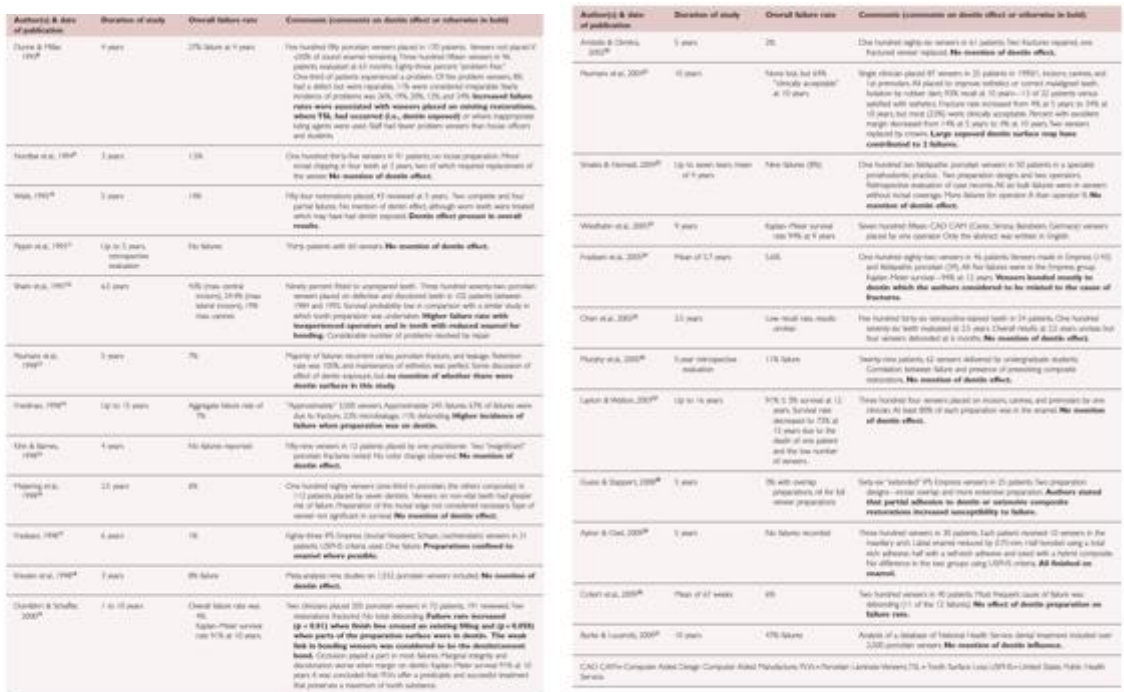
36 Ibid
37 Shetty A, Kaiwar A, Shubhashini N, Ashwini P, Naveen D, Adarsha M, Shetty M, Meena N. Survival rates of porcelain laminate restoration based on different incisal preparation designs: An analysis. J Conserv Dent. 2011 Jan;14(1):10-5.
38 Ibid

Another meta analysis conducted by Trevor Burke[39] discussed the porcelain survival rates as being rarely at 100% if the preparation is partially or almost completely in *dentin*. Burke stated that the dentin preparation is not retentive, leading to higher failure rates. The ideal preparation for porcelain veneers remains within enamel[40].



(Figure 12: Burke, 2012)

Guess and Stappert further studied preparation designs in a five-year study in vivo[41] on extended pressed ceramic veneers of two specific design types: OV (*Modified Overlap Veneer Preparation*) and FV (*Full Veneer*). Guess' results indicate palatal

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[39] Burke FJ. [Survival rates for porcelain laminate veneers with special reference to the effect of preparation in dentin: a literature review.]() J Esthet Restor Dent. 2012 Aug;24(4):257-65.

[40] Ibid

[41] Guess PC, Stappert CF. [Midterm results of a 5-year prospective clinical investigation of extended ceramic veneers.]() Dent Mater. 2008 Jun;24(6):804-13. Epub 2007 Nov 19. PubMed PMID: 18006051.

extensions of full veneers are not linked to higher fail rates. A particular combination of reliable bonding, ceramic fatigue, and fracture resistance are factors for success[42].

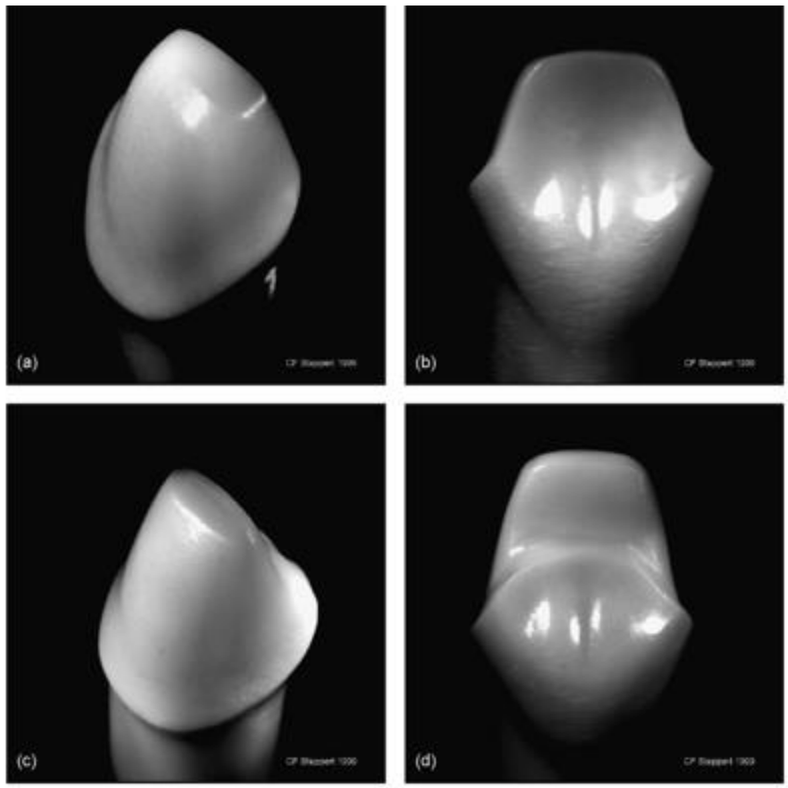

Fig. 1 – Modified overlap veneer preparation (OV) (butt joint) (a) labial-incisal-proximal view; (b) palatal extension and full veneer preparation (FV) (c) labial-incisal-proximal view; (d) palatal extension.

(Figure 13: Guess, 2008.)

Veneer preparations were performed as follows:

"The labial surface was axially reduced by 0.3–0.5mm (#878.204.012, #868B.314.018; Komet Dental). Cervically, a shallow chamfer (0.5mm) was prepared epi-gingivally. The proximal reduction was 0.5–0.7mm. The incisal edge was shortened by a minimum of 0.5–1.5mm. Full veneer (FV) restorations differed by preparing an extensive 0.5–0.7mm deep rounded shoulder in palatal area. Extension of palatal preparation was generally limited to the cingulum area, however, an extensionwas justified with large tooth defects (Fig. 1c and d). Palatal centric contact points on the ceramic surface were avoided, when applicable. All preparation margins were restricted by enamel. Labial epi-gingival preparation and controlled preparation depth enabled adhesive cementation mainly to enamel. All inner line angles were rounded. Preparation margins were not beveled."[43]

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42 Ibid

43 Guess PC, Stappert CF. Midterm results of a 5-year prospective clinical investigation of extended ceramic veneers. Dent Mater. 2008 Jun;24(6):804-13. Epub 2007 Nov 19.

Guess and Stappert concluded that a visibly pronounced extension of the ceramic into the palatal tooth area in the Full Veneer preparation was not linked to a higher failure probability as compared to the Overlap design. As with all restorations, the bonding of tooth, ceramic and luting composite and the fracture resistance of the ceramic are key factors for the long-term success of the extended veneer technique[44]. Peumans[45] agreed that in long term studies of veneer restorations with a 3mm deep palatal chamfer the survivability at five years is 92%, but drops off to 64% at ten years' time. It is important to note that these studies contradicted Magne's concerning the palatal concavity and tensile stresses are greatest in that region and resultantly cause failure[46]:

> *"This could be explained by the fact that the restoration margins were basically not located in the palatal concavity. For the overlap preparations palatal preparation of restoration margin remained coronal to the palatal concavity. For the full veneer preparations the restoration margin was located in the convex area close to the cingulum".*[47]

[44] Guess PC, Stappert CF. Midterm results of a 5-year prospective clinical investigation of extended ceramic veneers. Dent Mater. 2008 Jun;24(6):804-13. Epub 2007 Nov 19.

[45] Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. J Dent. 2000 Mar;28(3):163-77.

[46] Ibid

[47] Ibid

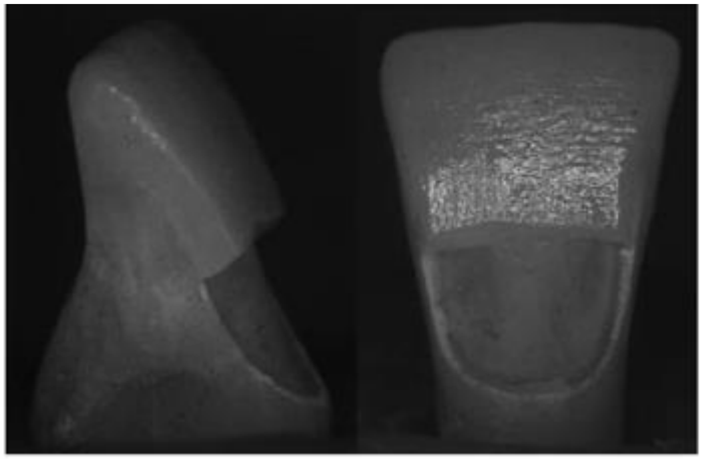

Fig. 4. Example for the fracture mode of the teeth with preparation of the incisal edge.

(Figure 14: Guess, Stappert, 2008.)

Recall that Calamia[48] preferred an *incisal reduction to form a slight overlap*. More recent studies, especially by Hui[49], however, demonstrated higher resistance to load for porcelain veneers without overlap, or revealed no difference between different types of incisal margins[50]. A comparable study performed by Akoğlu[51] with 75 in vitro incisors with five preparation designs confirm that a 2 mm incisal reduction advocated by Calamia exhibited fracture resistances similar to the enamel and dentin of intact teeth[52]. Castelnuovo's study[53] concentrated also on design types, wherein fifty human extracted teeth were distributed into five preparation design groups similar to Akoğlu (Group 1: no incisal reduction; 2 mm incisal reduction, no palatal chamfer; 1mm incisal, 1mm palatal;

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48 Calamia JR. The etched porcelain veneer technique. N Y State Dent J. 1988 Aug-Sep;54(7):48-50.

49 49 Hui KK, Williams B, Davis EH, Holt RD. A comparative assessment of the strengths of porcelain veneers for incisor teeth dependent on their design characteristics. Br Dent J. 1991 Jul 20;171(2):51-5.

50 Ibid

51 Akoğlu B, Gemalmaz D. Fracture resistance of ceramic veneers with different preparation designs. J Prosthodont. 2011 Jul;20(5):380-4. doi: 10.1111/j.1532-849X.2011.00728.x. Epub 2011 Jun 1.

52 Ibid

53 Castelnuovo J, Tjan AH, Phillips K, Nicholls JI, Kois JC. Fracture load and mode of failure of ceramic veneers with different preparations. J Prosthet Dent. 2000 Feb;83(2):171-80.

4mm incisal reduction, 1 mm palatal chamfer; Control group, no preparation) using IPS Empress as the restorative material. According to Calstenuovo, there was conflicting evidence on whether or not the veneers should be exposed to occlusal loads and function for his study. Toh[54] says there should not be whereas Friedman[55] says yes. Castelnuovo also directed the clinician to remember the previously advocated preparation designs by his predecessors:

1. Calamia's analysis advocated the Incisal Butt-Joint design to increase strength and positive seating upon delivery of the restorations
2. Hui favors Feathered Incisal edge (Window Prep) where the incisal edge is preserved
3. Weinberg[56] advocates 1mm incisal round reduction & rounded line angles
4. Sheets and Taniguchi[57] preferred a chamfer with a heavy lingual chamfer

Castelnuovo chose preparations with reductions of 0.3mm gingival thickness, 0.5mm for the mid - 1/3rd thickness, IPS Empress class veneers as the restorative material and Variolink cement as his bonding agent. According to Reitz[58], previous studies that compare the fracture strengths of different designs loaded the restorations *directly* at the incisal edge and *parallel* to the long axis of the tooth. Reitz indicated the actual orthognathic interincisal angle is *135 degrees*, and any stressors introduced are not usually directed parallel to the long axis of the tooth. Castelnuovo predicted that forces directed incisally would move the ceramic veneers facially and he focused solely on

54 Toh CG, Setcos JC, Weinstein AR. Indirect dental laminate veneers--an overview. J Dent. 1987 Jun;15(3):117-24.

55 Friedman MJ. A 15-year review of porcelain veneer failure--a clinician's observations. Compend Contin Educ Dent. 1998 Jun;19(6):625-8, 630, 632.

56 Weinberg LA. Tooth preparation for porcelain laminates. N Y State Dent J. 1989 May;55(5):25-8.

57 Sheets CG, Taniguchi T. Advantages and limitations in the use of porcelain veneer restorations. J Prosthet Dent. 1990 Oct;64(4):406-11.

58 Reitz PV, Aoki H, Yoshioka M, Uehara J, Kubota Y. A cephalometric study of tooth position as related to facial structure in profiles of human beings: a comparison of Japanese (Oriental) and American (Caucasian) adults. J Prosthet Dent. 1973 Feb;29(21):157-66.

horizontal load (mandibular to maxillary direction[59]. Castelnuovo concluded that the 2mm enamel Butt-Joint preparation design was the strongest and it offered many advantages to treatment, including conservation of tooth structure, flexibility of porcelain veneer fabrication and ease of manipulation for cementation and insertion.

Some researchers believe that individual situations demand operator flexibility and different designs. Zarone proposed the chamfer preparation for central incisors, whereas window preparation displayed better results for canines. Yet both preparations can be adopted in the restoration of lateral incisors[60]. Still others postulate that no single design has any influence on long-term performance. Guess again stated that both an overlap (Butt-Joint) design and the extended palatal veneer have similar viability at the seven-year mark[61].

Consider next the Prepless veneer design. Vanlioğlu pointed out that there has been heavy marketing by companies with specific reference to practitioners and consumers alike recently. The companies advocate no preparation designs, which, by all standards, have the advantage of a minimal need for anesthesia, minimal or complete absence of postoperative sensitivity, maximum bonding of the restoration to enamel, minimal flexural stress, longer lasting restorations, high potential for reversal should the restoration no longer be desired, and higher levels of acceptance of treatment among

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59 Castelnuovo, 2000.

60 Zarone F, Apicella D, Sorrentino R, Ferro V, Aversa R, Apicella A. Influence of tooth preparation design on the stress distribution in maxillary central incisors restored by means of alumina porcelain veneers: a 3D-finite element analysis. Dent Mater. 2005 Dec;21(12):1178-88.

61 Guess PC, Selz CF, Voulgarakis A, Stampf S, Stappert CF. Prospective clinical study of press-ceramic overlap and full veneer restorations: 7-year results. Int J Prosthodont. 2014 Jul-Aug;27(4):355-8

patients[62]. LeSage also agreed that a closer look at no preparation designs is needed[63]. Jahaveri[64] discussed the differences between porcelain veneer design types and indicated *treatment planning* as the deciding factor in determining which methodology should be employed. Jahaveri advocated properly conducted esthetic evaluations can reveal conditions such as severe discoloration, protrusion, or crowding that require reduction to achieve the desired aesthetic and functional results.

Disadvantages of the no-preparation / Prepless technique include a bulky appearance which can immediately appear as unnatural to the casual observer:

> "*For no-preparation veneers, the esthetic results are variable; some of these restorations appeared too bulky and over contoured, while others have relatively acceptable esthetics. To maintain the original tooth shape, it often requires the clinician to remove a slight-to-moderate amount of enamel when making the tooth preparations. However, in order to avoid tooth sensitivity and pulpal death, tooth preparation should be made in enamel whenever possible. Nevertheless, bulky veneers should be avoided, because they appear* false *to the observers. Therefore, flattening of prominent cervical contours must be done to avoid overcontouring of the veener. Some clinicians feel that there is a more optimum esthetic potential when teeth are prepared with a light chamfer* "[65]

Periodontal issues may also arise due to the overbulking of the restoration at the gingival margin (thereby interfering with the gingival emergence profile). Additionally, the width of the tooth being restored cannot be altered significantly. Difficulty in masking severe

[62] Vanlıoğlu BA, Kulak-Özkan Y. Minimally invasive veneers: current state of the art. Clin Cosmet Investig Dent. 2014 Nov 28;6:101-7.

[63] LeSage B. Revisiting the design of minimal and no-preparation veneers: a step-by-step technique. J Calif Dent Assoc. 2010 Aug;38(8):561-9.

[64] Javaheri D. Considerations for planning esthetic treatment with veneers involving no or minimal preparation. J Am Dent Assoc. 2007 Mar;138(3):331-7.

[65] Ibid

staining and discoloration with thin veneers employed in no preparation design is also encountered with prepless designs:

> *"If thin veneers were constructed, the final result in these cases is often compromised because of the use of underlying opaque porcelains, the veneers will exhibit very high value and lack of vitality.3 The color discrepancy is due to the relative thinness of the veneer and the light passing through it can make the color of the underlying preparation show through.32 If the patient requests a significant shade change, the dentist must overcome that by increasing the thickness of the restoration by deepening the preparation.3, 33, 34 This will allow room for the technician to block out the underlying tooth color and achieve the desired color change."*[66]

Jahaveri stipulated that in order to achieve the desired result, a number of considerations must be acknowledged and deciphered by the practitioner: type of porcelain to be used, the amount of tooth removal required, and the goals of aesthetic treatment. Strassler indicated that prepless systems, specifically Lumineers by DenMat, have a mean long-term stability of 15.2 years[67] using their proprietary bonding system. Another study involving 546 Chinese patients with tetracycline staining indicated Lumineers's minimal preparation design was successful in masking such stains[68].

The question now arises whether or not there is a definitive advantage to either style of preparation. Previous in-vitro studies have been successful in determining average fracture strength resistance of ceramic restorations using *ivorine teeth* akin to dentiform teeth used in preclinical laboratory work by Bulbule and his colleagues as

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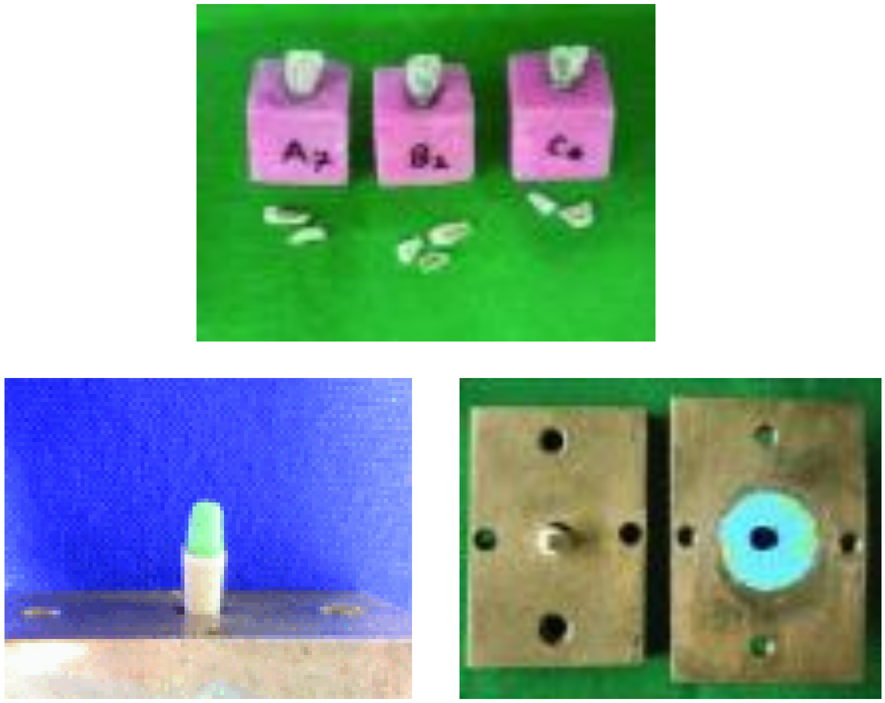
66 Ibid

67 Strassler HE. 432 Long term clinical evaluation of cerinate porcelain veneers. In: International Association for Dental Research (IADR) general session; 2005 Mar 9-12; Baltimore, MD

68 Chen JH, Shi CX, Wang M, Zhao SJ, Wang H. [Clinical evaluation of 546 tetracycline-stained teeth treated with Cerinate laminate veneers]. Zhonghua Kou Qiang Yi Xue Za Zhi. 2003 May;38(3):199-202.

recently as 2014[69]. Average fracture loads found were in excess of 715.13 N, similar to fracture loads expressed by natural teeth[70].



(Figure 15: Bubule, 2014)

May also tested fit precision of AllCeram crowns using Ivorine teeth by Kilgore[71], with marginal gaps below 70 microns, acceptably described as a precision fit one expects similarly with actual extracted human teeth. Zahran described fracture and fatigue resistance of all-ceramic restorations with Ivorine teeth in an in vitro study[72], with loads encountered maximally prior to failure as 1459 Newtons. Notably, Alghazzawi[73] and his cohorts compared differing materials for veneers with three different types of veneer

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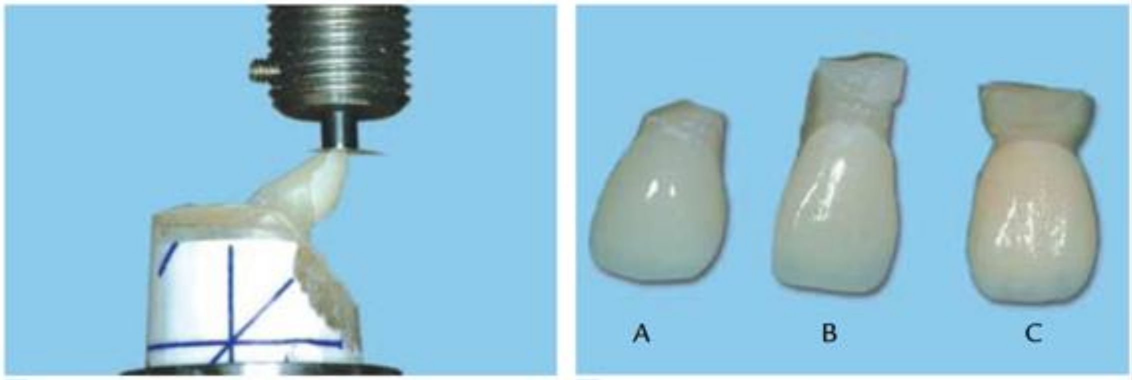
[69] Bulbule N, Motwani BK. Comparative study of fracture resistance of porcelain in metal ceramic restorations by using different metal coping designs- an in vitro study.J Clin Diagn Res. 2014 Nov;8(11):ZC123-7.
[70] Ibid
[71] May KB, Russell MM, Razzoog ME, Lang BR. Precision of fit: the Procera AllCeram crown. J Prosthet Dent. 1998 Oct;80(4):394-404.
[72] Zahran M, El-Mowafy O, Tam L, Watson PA, Finer Y. Fracture strength and fatigue resistance of all-ceramic molar crowns manufactured with CAD/CAM technology. J Prosthodont. 2008 Jul;17(5):370-7.
[73] Alghazzawi TF, Lemons J, Liu PR, Essig ME, Janowski GM. The failure load of CAD/CAM generated zirconia and glass-ceramic laminate veneers with different preparation designs. J Prosthet Dent. 2012 Dec;108(6):386-93.

preparations with ivorine teeth from Columbia dentiform using a lateral incisor as their test subject. Finally, Lin and his cohorts performed similarly-designed research in testing different porcelain systems on different veneer preparation designs on Ivorine maxillary lateral incisiors as well, yielding similar results[74]. The foundation for usage of ivorine teeth as test subjects has thus been well-documented and is considered as acceptable.

1 Two tooth preparation designs, incisal overlapped preparation (IOP) (A, top and bottom) and three-quarter preparation (TQP)(B, top and bottom).

(Figure 16: Alghazzawi, 2012)

[74] Lin TM, Liu PR, Ramp LC, Essig ME, Givan DA, Pan YH. Fracture resistance and marginal discrepancy of porcelain laminate veneers influenced by preparation design and restorative material in vitro. J Dent. 2012 Mar;40(3):202-9.



2 Loading apparatus including loading piston, polymeric material, cemented veneer on composite resin abutment, and acrylic resin block with directing loading to 135 degrees.

3 Examples of fractured cemented veneer-on-composite resin abutments after loading to failure. (A) Glass-ceramic, (B) Feldspathic porcelain, (C) Zirconia.

(Figure 17: Alghazzawi, 2012)

PURPOSE

To compare the total fracture strength of ceramic veneers placed on a Butt-Joint Preparation and a Prepless Veneer design.

HYPOTHESIS

The Butt-Joint preparation will have a higher fracture strength than the Prepless Veneer design.

MATERIALS AND METHODS

The tests utilized maxillary right central incisors, tooth #8, Ivorine teeth from Columbia Dentiform (Model #1860P08V EP TPR-860 8/V, Columbia Dentoform Corporation, Long Island City, NY). Twenty-five samples will employ a standardized

Butt Joint veneer preparation design as per the design advocated by Calamia, manufactured from a single preparation design by the author and replicated at the Columbia Dentoform manufacturing facility.   The diamond burs utilized include the round end fine and coarse tapered diamond (Neodiamond 1114.10C, lot 150903; 1114.10F, lot 160503; Microcopy, 3120 Moon Station Rd NW, Kennesaw, GA 30144), x-long pointed cone (Neodiamond 1312F/lot 151028, Microcopy), 30 micron finishing pointed cone (Neodiamond 3314.8VF, Microcopy), and the depth cutting bur (Brassler C72464 0.5mm, Brassler, 1 Brassler Blvd, Savannah, GA 31419). A final polish with flour pumice (Dazzle pumice, Whip Mix, 361 Farmington Ave, P.O. Box 17183, Louisville, KY 40217) and water was employed to effect a uniform and smooth surface preparation finish.

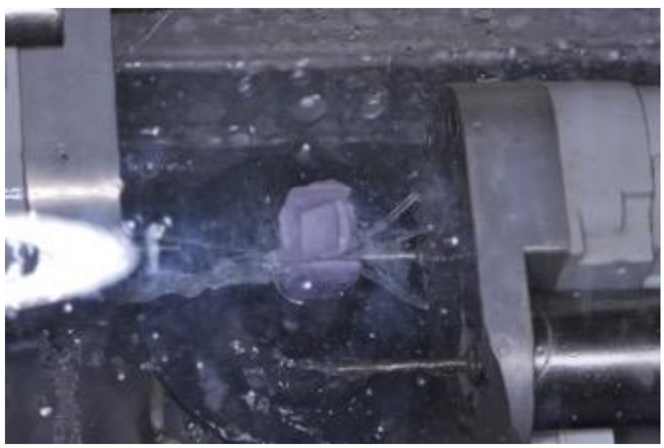
(Figure 18: preparation design for butt joint veneers on Ivorine Teeth)

Twenty-five ivorine teeth will replicate the prepless design (no modification to the ivorine tooth, (Model # 186008 T-860 (8) Columbia Dentoform Corporation, Long Island City, NY). A total of fifty samples will be tested.

A single representative ivorine tooth from each preparation type was scanned with the Sirona CAD/CAM system (Sirona Dental Systems USA, 4835 Sirona Drive, Suite 100, Charlotte, NC 28273) using the current software upgrade (version 4.0.4) and the OmniCam system. Step one involved the basic design parameters on the CAD/CAM unit: dimensional parameters included 80 microns minimal luting space, 0.5 mm thickness (500 microns) of the final prosthesis, and an occlusal offset of 0 microns. Step two required the digital impression of the prepared typodont tooth, opposing arch and bite registration.   No powder was used due to the increased abilities of the upgraded Omnicam.

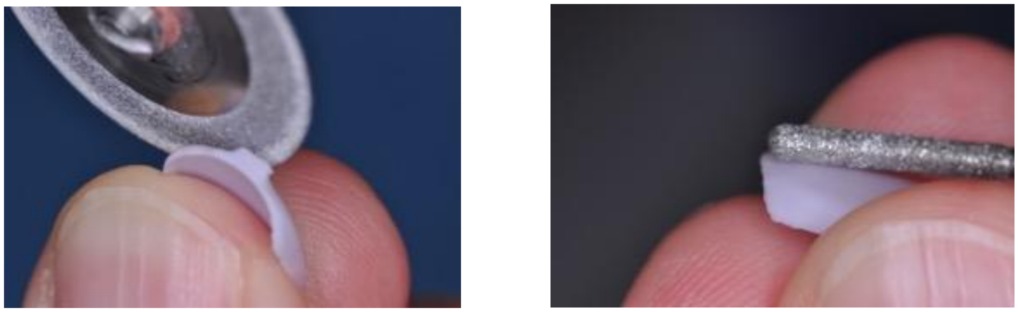
(Figure 19: design of CAD/CAM eMax Veneers)

Step three involved the orientation and alignment of the digital impressions, similar to conventional methods of mounting final casts on a semiadjustable articulator. Step four required the restoration margins be demarcated using the margin locating tool. Step five allows the CAD/CAM program to propose the prosthesis. Step six allowed for the analysis and evaluation of the proposed prosthesis (shape, contour, surface texture, interproximal extensions, interproximal contacts, occlusion), and allowed for any corrections if necessary to the physical parameters of the restoration.

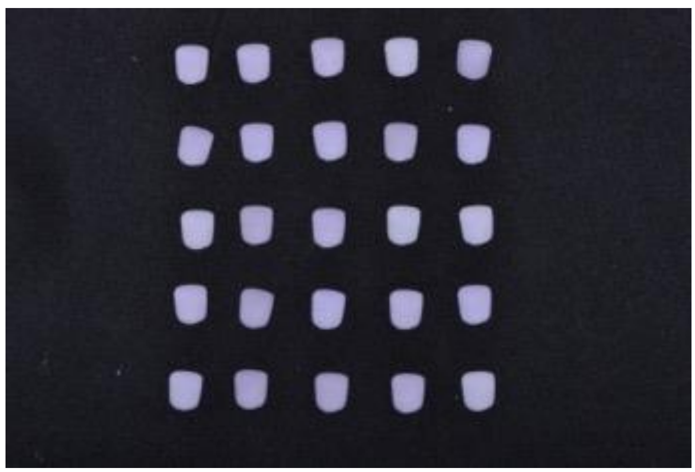


(Figure 20: milling chamber and fabrication of veneer prosthesis)

The final step involved the placement of the sprue and final approval before milling. All restorations were milled using C12 size IPS eMax CAD lithium disilicate blocks (Ivoclar Vivadent Inc., 175 Pineview Dr., Amherst, NY 14228) in the Cerec MC XL Milling Chamber (Sirona Dental Systems USA). The restorations were then cleansed with a steaming unit (HotShot 1300 watt Steaming unit, 1101-023-005, Silfadent, Italy) and subsequently rinsed under room temperature water. The sprue on each restoration was removed with an electric handpiece (Kavo type 4911 electric handpiece (sn68287), Kavo, 11727 Fruehauf Dr, Charlotte, NC 28273)



(Figure 21: sprue removal and polishing)

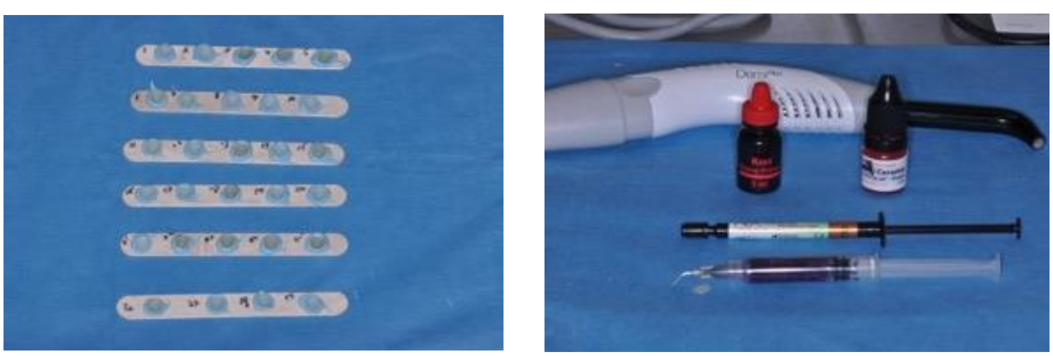


(Figure 22: polishing and finishing of restorations in blue state)

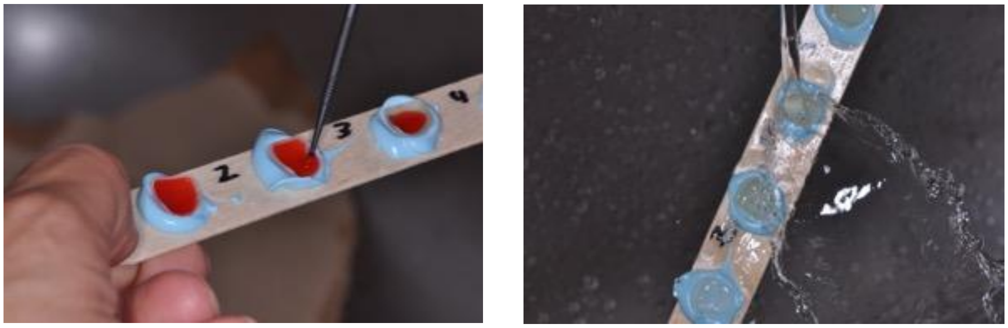
Final crystallization of each prosthesis was performed using the Sirona glazing oven (Sirona Programat P700, Sirona Dental Systems USA, 4835 Sirona Drive, Suite 100, Charlotte, NC 28273) utilizing the crystallization mode at 1800 degrees Fahrenheit for twenty-five minutes. Once completed, the restorations were allowed to cool to room temperature for ten minutes before physical handling and final inspection prior to cementation.

(Figure 23: Crystallization of restorations)

Cementation of restorations was performed with Nexus NX3 light cure system (translucent shade, lot 5814182 Kerr Corporation, 1717 West Collins, Orange, CA 92867). Each Veneer was prepared prior to cementation by conditioning the intaglio surface of the restoration with IPS Ceramic Etching Gel / hydrofluoric acid 9% for twenty seconds, (Ivoclar Vivadent Inc., 175 Pineview Dr., Amherst, NY 14228, Lot P72319) then rinsed thoroughly for twenty seconds to ensure removal of the acid etch. A second etch utilizing hydrophosphoric acid (HF) 37% (Kerr Corporation, 1717 West Collins, Orange, CA 92867) was placed for twenty seconds to remove any further contaminants embedded on the intaglio surface of each restoration.

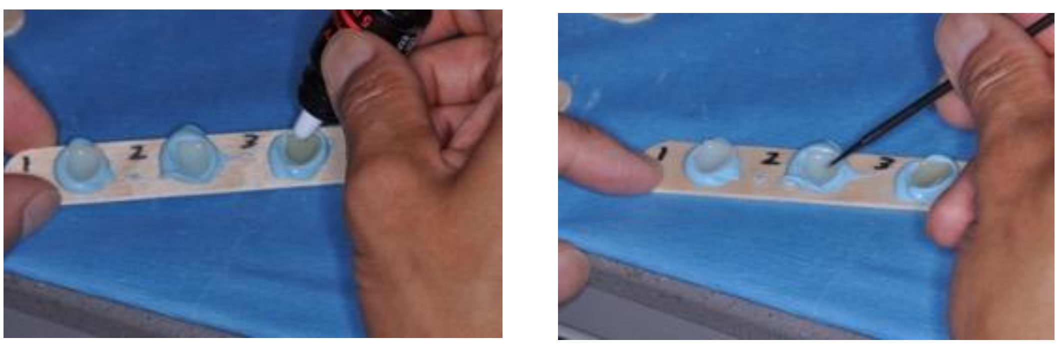


(Figure 24: preparation handling setup and armamentarium)

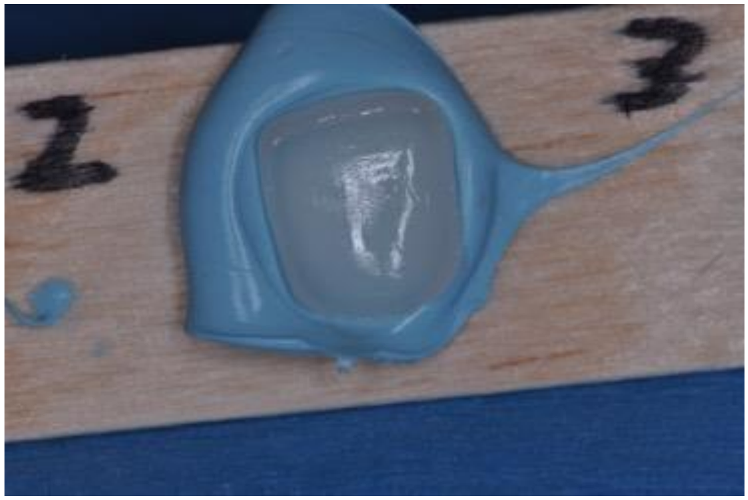


(Figure 25: preparation of restorations with HF 9% etch)

After air drying the intaglio surfaces, each was coated with a Silane coupling agent liquid (Kerr Corporation, 1717 West Collins, Orange, CA 92867 serial number 5837559) for sixty seconds, then air dired gently and checked to ensure maximal coverage.

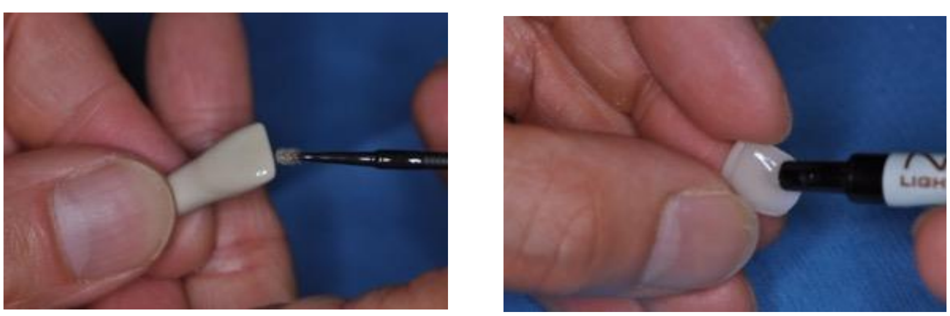


(Figure 26: silane coupling agent application to intaglio surfaces)

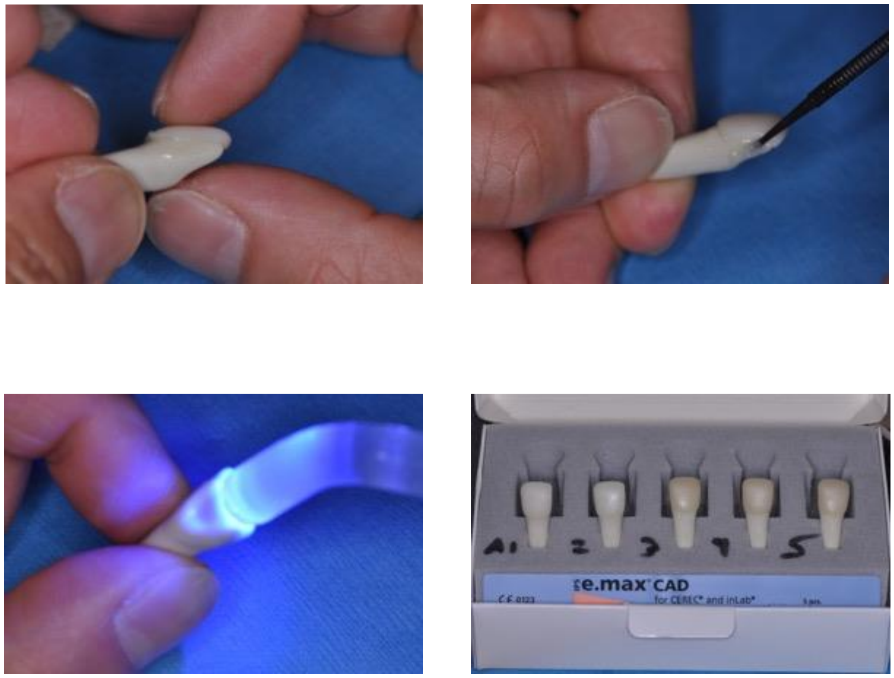


(Figure 27: visual inspection of application of Silane coupling agent to intaglio surface of restoration)

Each ivorine tooth surface was etched with Hydrophosphoric Acid (H_2PO_4) 37% for twenty seconds, rinsed thoroughly for twenty seconds and then air dried. Two coats of Optibond Solo Plus Bonding agent ((Kerr Corporation, 1717 West Collins, Orange, CA 92867, Lot 5839764) were applied to the surface of each test subject, allowed to sit for twenty seconds and gently air dried for five seconds before curing with a DEMI cordless LED Curing light for ten seconds.



(Figure 28: bonding and luting of restorations)



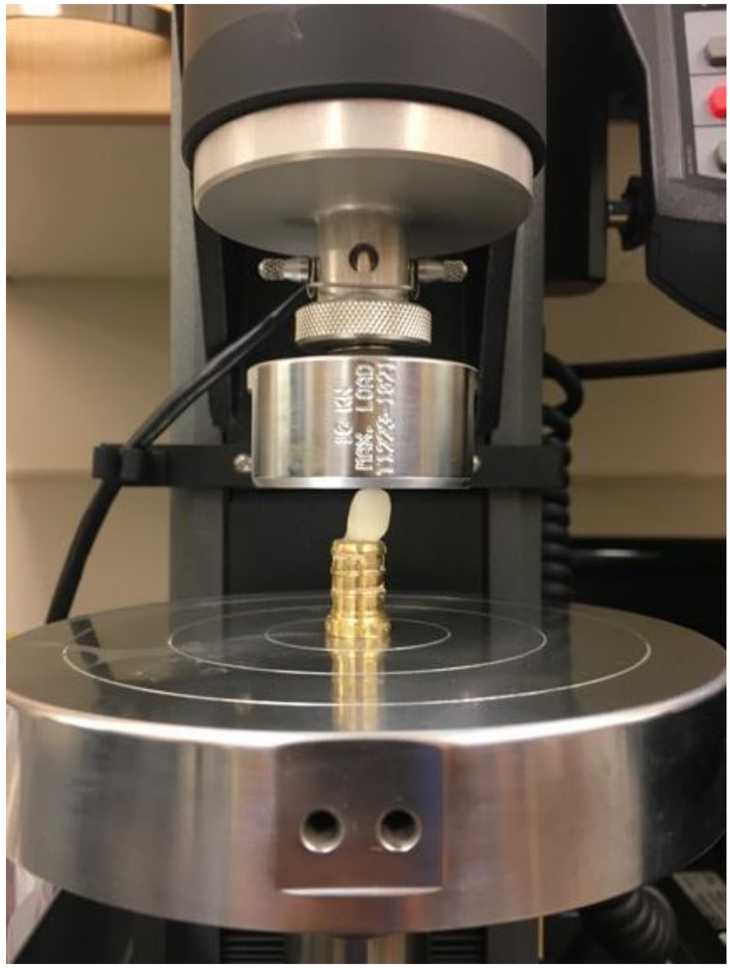
(Figure 29: cementation of test subject restorations)

Application of Nexus NX3 translucent light cured resin cement to each veneer intaglio surface and then placed onto the ivorine teeth and excess material was wiped away using a microbrush. Light curing of the cement was performed for twenty seconds on both the facial and inciso-lingual aspects of the restorations respectively for a total of forty seconds. Examination of the marginal surfaces was performed to ensure no voids were present and excess cement was removed using a number 15 scalpel (Miltex 15c surgical scalpel, lot C13003, Integra Miltex, 589 Davies Dr, York, PA 17402). All surfaces were polished with a ceramic polishing tip in a slow speed handpiece (Midwest Shorty (429682) and straight cone (095729), Dentsply, 221 West Philadelphia St, York, PA 17401).

Each individual sample was mounted at a buccolingual inclination angle of 135 degrees between the long axis of the abutment and the horizontal plane into an acrylic-infused metallic mounting jig (Jet acrylic resin, Lang Dental Mfg Co Wheeling, Ill) (1/2" brass test plug, UC514LFA5, Reliance Worldwide Co., 2727 Paces Ferry Rd SE, Building Two, Suite 1800, Atlanta, GA 30339). The angulation simulated the intraoral position of each subject as they relate biomechanically in ideal occlusion to the mandibular dentition. The Instron device (model Apex 5943; Satec Systems Inc., Grove City, PA) was used to simulate the forces applied in a vertical direction. Specimens were loaded at 0.5 mm/min crosshead speed until a drop in load was recorded, indicating that potential catastrophic events to the tooth had occurred including cracking, fracture or full failure of the restoration.

(Figure 30: test subjects mounted and ready for load)

(Figure 31: Instron, Model Apex 5943; Satec Systems Inc., Grove City, PA)



(Figure 32: Test Subject at loading)

A one-way between subjects analysis of variance (ANOVA) was conducted to compare the effect of the preparation designs on the fracture resistance of the right central incisor samples. P-values < 0.05 were considered statistically significant. Partial eta squared values were calculated to determine effect sizes for statistically significant results. Data were analyzed using SPSS (Statistical Package for the Social Sciences version 22.0, SPSS, Chicago, IL USA).

Software and Firmware updates to the Instron 5943 were performed on 30AUG16 by Mr. James Beale, Instron Corporation. BlueHill 3 software was uploaded and updated prior to the initiation of the test. The model for the test methodology followed the formula:

Test method → create → compression method → Library → compression example

Load threshold was computed at 1.5 x of 5 Newtons. Break detection was initiated at this point and acceleration was set to 25mm/min. When 1 N is detected in change, the autobalace goes into effect, the force applied from the Instron unit reset and the test then begins. Warmup time of 15 minutes is required of the Instron unit and then the computer can be powered on to load and sync with the instron device. Parameters to be measured by the Instron device were: Load at break, Extension at break, Maximum Load, Extension and Maximum load, and the Modulus of elasticity.

DATA RESULTS

Table 1: Prepless Veneer Design

	Load at Break [N]	Extension at Break [mm]	Maximum Load [N]	Extension at Maximum Load [mm]	Modulus (Automatic) [MPa]
1	416.896	0.462	822.797	0.453	70.028
2	317.234	11.235	744.026	11.225	70.257
3	196.834	0.523	676.088	0.513	66.740
4	102.820	0.145	298.780	0.126	65.315
5	166.406	0.288	558.572	0.278	83.773
6	76.555	0.414	431.074	0.406	81.665
7	401.289	0.323	477.857	0.311	82.615
8	261.248	0.288	636.165	0.265	76.156
9	978.205	0.354	978.205	0.354	84.959
10	400.871	0.211	527.057	0.202	73.374
11	321.881	0.323	689.294	0.315	62.975
12	377.460	0.371	727.495	0.361	66.888
13	308.889	0.234	671.647	0.225	83.069
14	278.804	0.295	888.350	0.283	85.858
15	116.957	0.293	856.391	0.279	81.038
16	978.293	0.296	978.293	0.296	80.765
17	246.334	0.308	795.576	0.297	82.488
18	85.688	0.412	758.187	0.400	67.494
19	46.746	0.372	588.131	0.362	73.641
20	329.444	0.748	911.368	0.738	64.800
21	978.279	0.676	978.279	0.676	67.161
22	226.273	0.319	411.984	0.314	80.368
23	447.179	0.247	573.793	0.244	64.017
24	406.995	0.328	552.886	0.325	71.262
25	144.241	0.511	495.355	0.504	80.240
Mean	344.473	0.799	681.106	0.790	74.678
Standard deviation	266.22263	2.17837	190.53709	2.17834	7.69989
Minimum	46.746	0.145	298.780	0.126	62.975
Maximum	978.293	11.235	978.293	11.225	85.858
Range	931.547	11.090	679.513	11.099	22.883

Table 2: Prepless Veneer Design

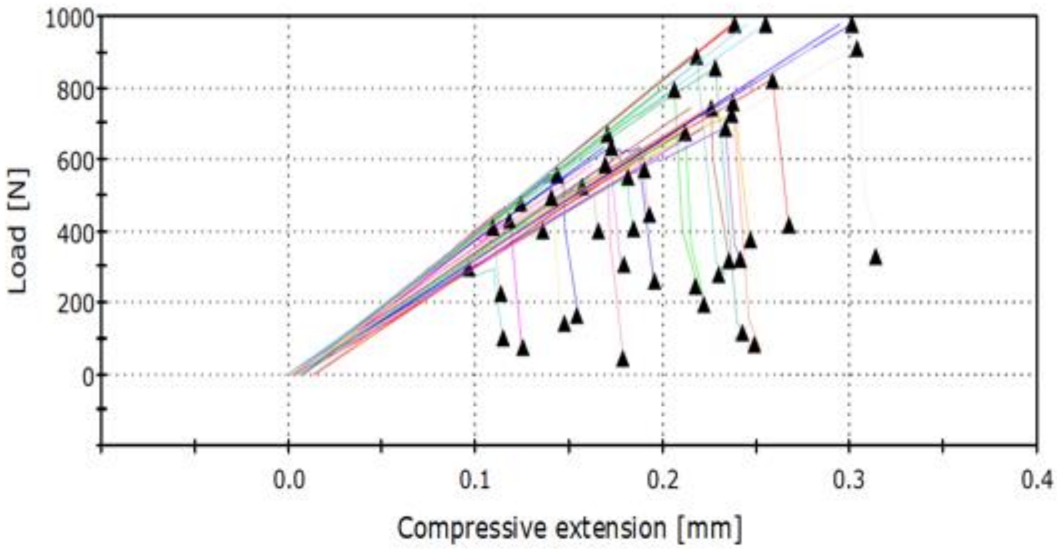
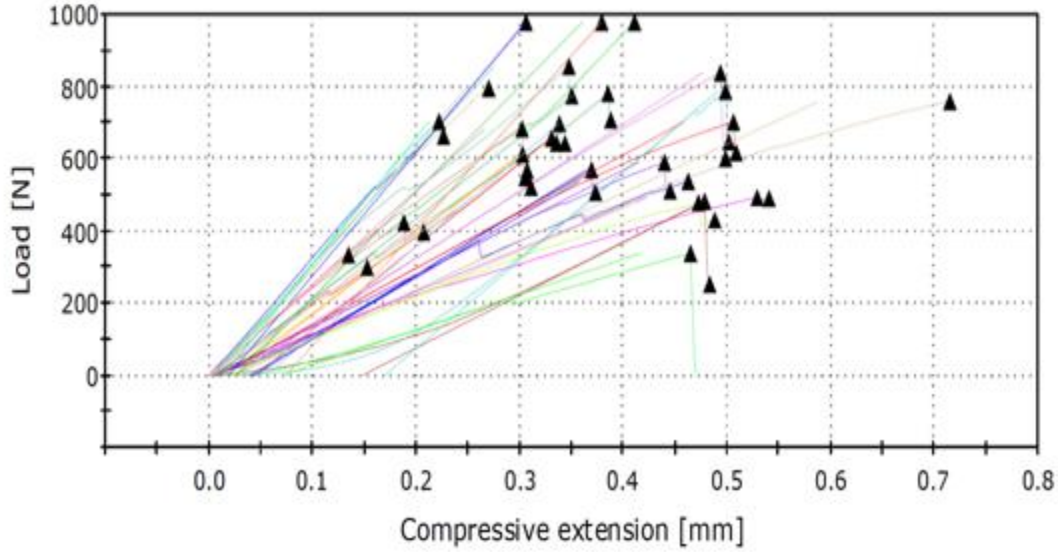


Table 3: Butt-Joint Veneer Design

	Load at Break [N]	Extension at Break [mm]	Maximum Load [N]	Extension at Maximum Load [mm]	Modulus (Automatic) [MPa]
1	644.445	0.487	658.537	0.482	46.118
2	252.902	3.254	483.407	3.250	29.140
3	337.699	2.625	337.699	2.625	19.470
4	647.527	0.610	787.859	0.606	48.868
5	538.917	0.578	538.917	0.578	33.834
6	491.177	4.035	493.896	4.023	23.382
7	430.968	0.706	479.314	0.690	24.357
8	507.980	0.462	571.430	0.459	35.520
9	616.868	0.570	702.895	0.567	31.410
10	760.149	1.095	760.149	1.095	26.777
11	513.113	7.248	591.361	7.243	29.006
12	568.235	0.680	613.489	0.676	44.312
13	601.909	0.636	838.453	0.631	37.054
14	774.606	0.482	856.440	0.480	62.518
15	707.735	0.665	781.601	0.662	44.823
16	642.861	0.624	698.362	0.618	49.268
17	978.255	0.532	978.255	0.532	58.491
X 18	978.290	0.442	978.290	0.442	64.373
19	396.480	0.571	424.263	0.553	48.780
20	522.045	0.346	550.120	0.341	39.327
21	978.334	8.972	978.334	8.972	68.220
22	795.090	8.562	795.090	8.562	67.748
23	548.994	5.733	683.445	5.730	51.820
24	663.758	0.523	704.466	0.519	70.324
25	300.242	0.225	333.729	0.207	51.531
26	866.138	10.035	866.138	10.035	69.169
Mean	603.457	2.410	660.306	2.405	44.451
Standard deviation	189.66795	3.12644	180.22908	3.12809	15.52024
Minimum	252.902	0.225	333.729	0.207	19.470
Maximum	978.334	10.035	978.334	10.035	70.324
Range	725.432	9.809	644.605	9.827	50.854

Table 4: Butt-Joint Veneer Design



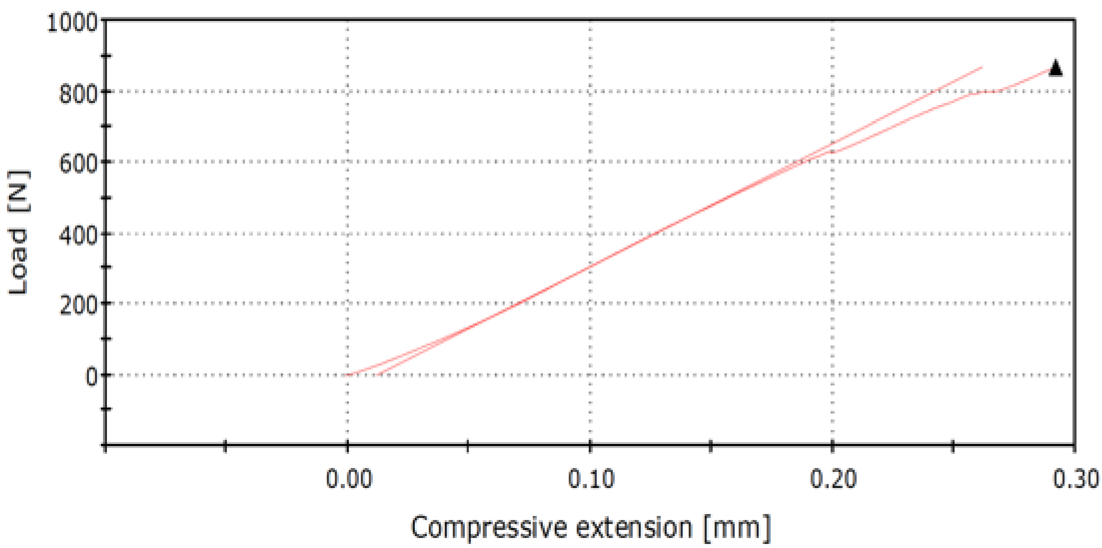


Table 5: Basic Descriptives

Descriptives

		N	Mean	Std. Deviation	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Load at Break (N)	Prepless Veneer	25	344.47	266.22	234.58	454.36	46.746	978.293
	Butt Joint Prep	25	603.46	189.67	525.17	681.75	252.902	978.334
Extension at Break (mm)	Prepless Veneer	25	0.80	2.18	-0.10	1.70	.145	11.235
	Butt Joint Prep	25	2.41	3.13	1.12	3.70	.225	10.035
Extension at Max Load (mm)	Prepless Veneer	25	0.79	2.18	-0.11	1.69	.126	11.225
	Butt Joint Prep	25	2.41	3.13	1.11	3.70	.207	10.035
Modulus (MPa)	Prepless Veneer	25	74.68	7.70	71.50	77.86	62.975	85.858
	Butt Joint Prep	25	44.45	15.52	38.04	50.86	19.470	70.324

Table 6: Descriptive Data

Descriptive Characteristics

	N	Mean	Std. Deviation
Load at Break (N)			
Prepless Veneer	25	344.47	266.22
Butt-Joint Preparation	25	603.46	189.67
Maximum Flexure Stress (MPa)			
Prepless Veneer	25	74.68	7.70
Butt-Joint Preparation	25	44.45	15.52
Extension at Break (mm)			
Prepless Veneer	25	0.80	2.18
Butt-Joint Preparation	25	2.41	3.13
Extension at Max Load (mm)			
Prepless Veneer	25	0.79	2.18
Butt-Joint Preparation	25	2.41	3.13
Maximum Load (N)			
Prepless Veneer	25	681.11	190.54
Butt-Joint Preparation	25	660.31	180.23

(a) *(b)* *(c)*

(Figure 32: sample results of test subjects detailing fractures: a: Inciso-Facio-lingual; b: Inciso-Facical; c: Facial)

The study included a total of fifty samples, divided evenly between the two preparation designs. Descriptive data for the two groups are shown in Tables 1-4. A one-way between subjects ANOVA revealed a significant differences and large effects from the preparation design on the load at break [$F(1, 48) = 15.69$, $p < 0.001$, $\eta_p^2 = 0.25$] and the Modulus [$F(1, 48) = 76.10$, $p < 0.001$, $\eta_p^2 = 0.61$]. The mean load at break (N) for the Prepless Peneer group was 344.47 (SD = 4.18), which was significantly lower than the mean for Butt-Joint preparation (M = 603.46, SD = 189.67). However, the mean modulus (MPa) of the Prepless veneer group (M = 74.69, SD = 7.70) was greater than the mean of the Butt-Joint preparation samples (M = 44.45, SD = 15.52).

Additionally, significant differences and moderate effect sizes were found between the preparations for both extension at maximum load [$F(1, 48) = 4.49$, $p = 0.04$, $\eta_p^2 = 0.09$] and extension at break [$F(1, 48) = 4.47$, $p = 0.04$, $\eta_p^2 = 0.09$]. The mean extension at maximum load for the prepless veneer group was 0.79mm (SD = 2.18) and

2.41mm (SD = 3.13) for Butt-Joint preparation. The mean extension at break for the prepless veneer group was 0.80mm (SD = 2.18) and 2.41mm (SD = 3.13) for Butt-Joint preparation. No difference was found between the groups with respect to maximum load, $p = 0.69$.

Table 7: Fracture Descriptives

Test Subject	**Butt-Joint** Fracture Location	**Butt-Joint** Fracture type	**Prepless** Fracture Location	**Prepless** Fracture Type
1	Debond	Adhesive	F	Static
2	F	Static	IF	Cohesive
3	IF	Cohesive	IF	Cohesive
4	IF	Cohesive	IF	Cohesive
5	F	Static	IF	Cohesive
6	F	Static	IL	Cohesive
7	DEBOND	Adhesive	IF	Cohesive
8	I	Static	F	Static
9	DEBOND	Adhesive	IL (*978N)	Cohesive
10	IL	Cohesive	F	Static
11	DEBOND	Adhesive	F	Static
12	I	Static	F	Static
13	F	Static	F	Static
14	F	Static	F	Static
15	IF	Cohesive	F	Static
16	IF	Cohesive	IL (*978N)	Cohesive
17	F	Static	IF	Cohesive
18	F	Static	F	Static
19	F	Static	IF	Cohesive
20	I	Static	IF	Cohesive
21	I	Static	IL (*978N)	Cohesive
22	F	Static	IF	Cohesive
23	IF	Cohesive	IF	Cohesive
24	DEBOND	Adhesive	F	Static
25	IL	Cohesive	IF	Cohesive

DISCUSSION

Fracture is the most common cause of failure with regards to veneer restorations. Greater fracture rates are related to patients that have unfavorable occlusion, parafunctional movements and cementation to existing restorations. There are three major categories in which a veneer has been demonstrated to fail: static, cohesive, and adhesive. If a segment of a veneer fractures but remains intact, this is known as a static fracture. Static fractures are caused by excessive loading of the restoration or polymerization shrinkage of the resin cement. The internal fit of the ceramic restoration and the amount of unsupported porcelain have direct relevance to the failure. Any fit discrepancy of 100 μm or less can prevent static fracture by minimization of internal stresses[75].

Tensile loads within the porcelain restoration from excessive functional / parafunctional loading will directly cause cohesive fractures. Enamel imparts stiffness to the tooth much like a metal coping does for a metal-ceramic crown. Removal of the enamel can directly affect the stress-strain distribution of the subsequent veneer because cohesive fractures occur within the body of porcelain. The resultant flexure under any load will result in a cohesive fracture. Maintenance of enamel at the Incisal and cervical areas is essential because any lack of adhesion can cause more stress upon load.[76]

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[75] Summitt, James B.. *Fundamentals of Operative Dentistry: A Contemporary Approach, 3rd Edition*. Quintessence Publishing (IL), 012006. p. 482.

[76] ibid

Lastly, an adhesive fracture is due to the direct failure of the bonding interface between the porcelain restoration, cement and the tooth. This can be a result of an improper bond or excessive occlusal load, with at least 86% of all adhesive fractures occurring at the cement / dentin interface[77].

Usage of ivorine teeth to simulate natural tooth conditions gives distinct advantages over the employment of natural teeth in this study. This is due to a number of factors, including: an inability to regulate properly the size, shape and amount of enamel per test subject, anatomic variations of each natural tooth, specific age of the tooth test subject in question, time of each tooth in a storage medium before selection and usage, and the effects of the storage medium has upon the modulus of elasticity of the tooth as Stappert and his cohorts described[78]. The method employed here as described previously in the methods and materials section allowed the author to effectively standardize the Butt-Joint preparation design and Prepless Veneer design by fabrication of one master preparation and then mass-producing the teeth in a controlled facility, thus allowing for greater quality control and regularity in the preparation designs. This feature could not be replicated with ease if the study had involved normal extracted human teeth and allowed for a distinct advantage over extracted human samples.

In the ensuing analysis of the data results, the greatest variation of the types of fractures involved the Butt-Joint preparation group. Facial, Inciso-facial, Incisal, Lingual

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77 Summitt, James B.. *Fundamentals of Operative Dentistry: A Contemporary Approach, 3rd Edition*. Quintessence Publishing (IL), 012006. p. 482.

78 Stappert CF, Ozden U, Gerds T, Strub JR. Longevity and failure load of ceramic veneers with different preparation designs after exposure to masticatory simulation. J Prosthet Dent. 2005 Aug;94(2):132-9.

and Inciso-lingual failures were noted in order of frequency. Five samples suffered complete adhesive fractures from the prepared tooth surfaces. A total of seven samples experienced cohesive failures, and thirteen samples had static fractures. In contrast, the Prepless Veneer designs had an almost equal number of facial (static) and Inciso-facial fractures (fifteen) at failure load, hence a greater number of cohesive than static fractures . The possibility that the design of the Butt-joint with clearly defined margins can result in favorable stresses at specific points due to clearly defined preparation surfaces versus the Prepless design with no standardized margins is demonstrated here.

Interestingly, four Prepless Veneer subjects were able to withstand forces in excess of 978 N to where fracturing of the restoration was observed. The total load at break, however, was significantly greater for the Butt-Joint preparation as compared to the Prepless Veneer design by a factor of 1.75 to 1. The deviation in the mean value at break of the Prepless design was significantly greater (266.22) than the Butt-Joint as well (189.67). This is shown by the variance of the load at break for the Prepless design, measured from 234.58 N to 454.36 N. This can be accounted for by the individual variance of each bond material, resin amount and surface preparation of each individual test subject by the author. The handling of the restorations and cementation process is an extraordinarily technique sensitive and time-consuming process. One misstep in the procedure can result in debonding or early failure as stated by previous authors. This study confirms this with the minimum and maximum results in each preparation design (Prepless Veneer = range 46.746 to 978.293; Butt-Joint Veneer = range 252.902 to 978.334).

Comparatively, the Butt-Joint preparation subjects have less variance (525.17 to 681.75, with more consisitency of loads at break measured per test subject). The extensions (elongation) at break and at maximum load was also greater for the Butt-Joint than the Prepless designs (2.41 to 0.8, 0.79 respectively), which gives cause to support the fact that it can better withstand loading forces to the elastic limit than the prepless design. The maximum load that both preparations could withstand before failure were similar (660.31 Butt-Joint versus 681.11 Prepless). Here, the choice of materials (IPS eMAX CAD / Lithium Disilicate ceramic) combined with bonded resin cement (Nexus NX3) and the preparation types (minimal thickness versus no preparation) led to this result.

It is intriguing that the modulus (MOE) for the Prepless Veneer design was greater than the Butt-Joint design (74.68 versus 44.45). This may be accounted by the fact that the total tooth structure was intact, and therefore imparts a greater degree of stiffness when resin and ceramic are effectively bonded to the surface, whereas a reduction of the surface, however minimal, and replacement with a veneer results in a lower modulus.

In review of the results, it stands that our original hypothesis is correct. This is attributable to effectiveness of the design of the Butt-Joint preparation. It possesses numerous advantages which became even more apparent when designing the final prostheses on the Sirona CAD/CAM unit. The Butt-Joint preparation has definitive chamfer margins at the cervical, interproximal and the incisal reduction surfaces. It is a conservative preparation, with reduction dimensions of 0.3, 0.5 and 2mm reduction of cervical, facial and incisal surfaces respectively. It should be noted that the reduction dimensions are influenced by the type of burs used and the practitioner's skill at employing them effectively. A definitive path of insertion allows for only one way the final prosthesis can be seated as was demonstrated when cementation of the test subjects was performed. The design allows for a superb level of stress and force distribution as previously described. Finally, the level of aesthetics the preparation can achieve is of great quality when combined with the proper choice of the restorative material in conjuction with the patient's existing dental conditions and desires. There is minimal detrimental effect on the periodontal status of the teeth, a result of well-defined margins and a seamless interface when the restoration is delivered properly.

In contrast, the Prepless Veneer system is an arbitrary design. Its very nature by intent is absolutely no reduction of tooth structure with maximum preservation of enamel. In theory this allows for maximum bond strength between the tooth structure and the restoration via cohesive and adhesive forces. The surface of the enamel is merely roughened prior to cementation to ensure the most efficient and maximal bond to enamel. Length, width and height of the restorations is limited by the original form of the preserved underlying tooth structure. This can pose a problem for the restoring dentist, especially if the desire to change size and shape is a deciding factor for treatment. Should the patient desire a shade change, the proposed prosthesis must be thicker to cover the base shade of the underlying dentition with an opaque layer. Control of the restoration design is difficult due to the designer's definition of margin and finish lines from the interproximal, cervical and incisal aspects. Several designs were fabricated with the CAD/CAM program before a final prosthesis was decided upon due to incomplete coverage of the surfaces to be restored and insufficient contours of the restoration. Delivery of the restoration also proved to be challenging. This is due to the lack of any clearly defined margins and thus variance of the seating of the restoration is dependent upon the clinician. Resultantly, final delivery and cementation can prove to be difficult for the operator and an undesired result can occur. Cleansability issues to the patient and are also of great concern. This is especially true at the gingival margin, where there is bulk of restorative material due to no prepared tooth margin and thus a lack of a smooth cavosurface margin. Thus, there is no uninterrupted cavosurface margin because there is no reduction and there must be sufficient thickness of the restoration to impart durability. Left uncared for, this can result in failure of the restoration. As observed from the study, the margin is both visibly and clinically observable and makes the design less than favorable when directly compared to the Butt-Joint design.

CONCLUSIONS

Given the limitations of this In-Vitro Study, the author finds the following conclusions based upon the results:

1. The Butt-Joint Veneer design withstood a greater load at failure than the Prepless Veneer design
2. The Butt-Joint design can tolerate a greater extension at load than the Prepless Veneer design, further describing its physical strengths
3. The Maximum Load at break (Fracture Strength) tolerated by both designs is very similar
4. The Modulus of elasticity of the Prepless design is greater than that of the Butt-Joint by a factor of 1.68:1
5. The Butt-Joint design displays favorability towards (in order of frequency) static fractures, with thirteen total samples, secondarily with cohesive fractures (seven samples) and adhesive fractures (five samples). The Prepless veneer design displayed a tendency towards more cohesive failures (fifteen samples) versus static failures (ten samples).
6. Potentially, the Prepless Veneer design has the greater bond strength, showing four test subjects that could withstand up to 978+ N of force before failure due to its inherent preservation of enamel tooth structure that can be bonded

7. Comparatively, fabrication of the Butt-Joint Veneer restoration was facilitated by definitive margins whereas the Prepless design was an arbitrary design with margins defined by the author and not any preparation
8. Aesthetically, the Butt Joint designs were more pleasing with minimal issues with cleansability, positive seating of the restoration
9. The Prepless Veneer design had greater variance in the seating of the restoration and a significantly thicker cervical margin

Porcelain veneers are an accepted and viable option of care for patients who wish to change the size, shape, color and dimensions of their existing dentition. Without question, the final decision as to the choice of treatment rests upon the practitioner, patient and technician. All parties must consider careful and detailed discussion of treatment options, both invasive and non-invasive, and the potential sequelae that may arise as a result of the selected treatment involved. Should the option for treatment be exercised, the proper methods of treatment planning, familiarization of the materials to be used, the precise execution of delivery and postoperative follow-up are essential to the success of the case and satisfaction of the patient. Based upon the aforementioned conclusions, the author can recommend the Butt-Joint preparation as the desired preparation design, with fracture strengths that are twice the value of the Prepless design and possessing the superior aesthetic value.

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